

Journal of the Royal Society of Arts

NO. 4924

FRIDAY, 30TH APRIL, 1954

VOL. CII

FORTHCOMING MEETINGS

WEDNESDAY, 5TH MAY, AT 2.30 p.m. 'Colour Television', by Commander C. G. Mayer, U.S.N.R., O.B.E., M.I.E.E., European Technical Representative, Radio Corporation of America. Sir Noel Ashbridge, B.Sc., M.I.C.E., M.I.E.E., Chairman, Radio Research Board, Department of Scientific & Industrial Research, will preside. The paper will be illustrated with a colour film and lantern slides.

THURSDAY, 6TH MAY, AT 5.15 p.m. COMMONWEALTH SECTION. 'The Forest Resources of the Colonial Territories and their Management', by F. S. Collier, C.B.E., Forestry Adviser to the Colonial Office. H. R. Blanford, C.B.E., I.F.S. (Retd.), late Chief Conservator of Forests, Burma, will preside. The paper will be illustrated with lantern slides. (Tea will be served from 4.30 p.m.)

WEDNESDAY, 12TH MAY, AT 2.30 p.m. PETER LE NEVE FOSTER LECTURE. 'The Society's House: An Architectural Study', by John Summerson, C.B.E., F.S.A., A.R.I.B.A., Curator, Sir John Soane's Museum. Professor A. E. Richardson, R.A., F.R.I.B.A., a Member of Council of the Society, will preside. The lecture will be illustrated with lantern slides.

MONDAY, 17TH MAY, AT 6 p.m. The first of three CANTOR LECTURES on 'The Chemistry of Leather', by Henry Phillips, D.Sc., F.R.I.C., Director, The British Leather Manufacturers' Research Association. The lecture will be illustrated with lantern slides. (See syllabus below.)

TUESDAY, 18TH MAY, AT 5.15 p.m. COMMONWEALTH SECTION. 'Engineering Developments in Central Africa', by Sir William Halcrow, M.I.C.E., M.I.Mech.E. Sir Gilbert Rennie, K.C.M.G., M.C., High Commissioner for the Federation of Rhodesia and Nyasaland, will preside. (Tea will be served from 4.30 p.m.)

WEDNESDAY, 19TH MAY, AT 2.30 p.m. ALFRED BOSSOM LECTURE. 'The Design of New Schools', by C. H. Aslin, C.B.E., F.R.I.B.A., County Architect, Hertfordshire County Council. Sir Griffith Williams, K.B.E., C.B., a Member of Council of the Society and late Deputy Secretary, Ministry of Education, will preside. The lecture will be illustrated with lantern slides.

MONDAY, 24TH MAY, AT 6 p.m. The second of three CANTOR LECTURES on 'The Chemistry of Leather', by Henry Phillips, D.Sc., F.R.I.C. The lecture will be illustrated with lantern slides. (See syllabus below.)

TUESDAY, 25TH MAY, AT 5.15 p.m. COMMONWEALTH SECTION. '*Progress Towards the Eradication of Leprosy from the British Commonwealth*', by Major-General Sir Leonard Rogers, K.C.S.I., C.I.E., M.D., F.R.C.P., F.R.S. Sir Selwyn Selwyn-Clarke, K.B.E., C.M.G., M.C., M.D., F.R.C.P., Chairman of the Commonwealth Committee, will preside. The paper will be illustrated with lantern slides. (Tea will be served from 4.30 p.m.)

SYLLABUS FOR CANTOR LECTURES ON THE CHEMISTRY OF LEATHER

The syllabus for the three CANTOR LECTURES to be delivered by Dr. Henry Phillips, on Mondays, 17th, 24th and 31st May, is as follows:

LECTURE 1. Structure of hides and skins. Preparation for tannage. Chemical composition of collagen and of organic and inorganic tannins.

LECTURE 2. Physical chemistry of collagen. Fine structure of collagen fibres. Comparison of collagen and leather fibres.

LECTURE 3. Chemistry of different methods of tanning. Properties of different leathers.

MEETING OF COUNCIL

A meeting of Council was held on Monday, 12th April, 1954. Present: The Earl of Radnor (in the Chair); Mr. F. H. Andrews; Sir Alfred Bosson; Sir Frank Brown; Mr. P. A. Le Neve Foster; Mr. John Gloag; Sir Ernest Goodale; Mr. A. C. Hartley; Dame Caroline Haslett; Dr. R. W. Holland; Sir Harry Lindsay; Mr. F. A. Mercer; Mr. J. A. Milne; Lord Nathan; Mr. E. M. Rich; Sir Andrew Rowell; Mr. Gordon Russell; Sir Harold Saunders; Sir John Simonsen; Mr. William Will; Sir Griffith Williams; Mr. J. G. Wilson; Sir John Woodhead, and Miss Anna Zinkeisen; with Mr. K. W. Luckhurst (Secretary) and Mr. R. V. C. Cleveland-Stevens (Assistant Secretary).

ELECTIONS

The following candidates were duly elected Fellows of the Society:

Adams, Alfred Charles Ernest, Twickenham, Middx.
Axten, F. Kennedy, Farnborough Common, Kent.
Betjeman, John, Wantage, Berks.
Bilsland, The Right Honble. Lord, M.C., D.L., LL.D., Aviemore, Inverness.
Bock, Jan Hugo, Dr. Ing., Stockport, Cheshire.
Bowerman, Bernard John William, Buckhurst Hill, Essex.
Brookes, Sir Norman Everard, Melbourne, Australia.
Browne, Sydney J., Shirley, Surrey.
Castle, Wilfrid Curtis, East Brighton, Victoria, Australia.
Chowen, William George, Exeter, Devon.
Cooper, Miss Mildred, A.T.D., Salford, Lancs.
Davids, Jacob, Westcliff-on-Sea, Essex.
Davis, George Wilfrid, B.Sc., A.C.G.I., M.I.Mech.E., London.

Davison, William Alec, Princes Risborough, Bucks.
 Fergusson, Miss Janey Anderson Weir, Alloway, Ayrshire.
 Fox, Philip Raymond Cedric, Singapore.
 Gotlop, Philip, London.
 Grattan, Henry, Romford, Essex.
 Hackett, Douglas Chambers, Loughborough, Leics.
 Hampshire, Mrs. June Muriel, London.
 Hance, Frank, Northants, Lincs.
 Hancock, Thomas Herbert Hubert, A.R.I.B.A., M.T.P.I., Singapore.
 Hodge, Antony Thornton, Lees, Lancs.
 Hutchings, Philip, Melksham, Wilts.
 Joseph, Michael, Old Basing, Hants.
 Lane, Godfrey H. A., London.
 Long, Norman William, Toronto, Ontario, Canada.
 Lovett, Arthur Lewis, Ilford, Essex.
 Luyken, Henry Martin, F.R.I.B.A., A.M.I.Struct.E., Leigh-on-Sea, Essex.
 McLean, Robert, Cheam, Surrey.
 Macnair, Kenneth Charles, A.R.I.B.A., Singapore.
 Marbach, Peter L., Bradford, Yorks.
 Myles, Cyril Ernest Thomas, Brierley Hill, Staffs.
 O'Donnell, William Arthur, East Croydon, Surrey.
 Richards, William, Featherstone, Yorks.
 Robinson, Colonel Victor Owen, M.C., O.B.E., T.D., Chesterfield, Derbyshire.
 Robinton, Professor Madeline Russell, M.A., Ph.D., New York, U.S.A.
 Rose, Laurence Melville, London.
 Scott, William Richard, A.M.I.C.E., Singapore.
 Sherrin, Reginald Daniel, Rochester, Kent.
 Smith, Oliver Douglas, Alcester, Warwicks.
 Stellatos, Gerassimo Basile, Alexandria, Egypt.
 Tiranti, Alec, London.
 van der Byl, Mrs. Joy Clare, Caledon, Cape, South Africa.
 Walker, Douglas Stanley Mackenzie, St. Albans, Herts.
 Walmsley, Mrs. Mary Jane, Blackburn, Lancs.
 Warner, Francis Leon, Dover, Kent.
 Whitbread, Humphrey, M.A., Cardington, Beds.
 Wolfe-Murray, Lt.-Col. David Knightley, London.

Associate Members

Farrell, Patrick Hugh, London.

The following have been awarded Associate Membership as winners of Industrial Art Bursaries in 1953:

Bamfield, Miss Olive Teresa Margaret, Montford Bridge, Shropshire.
 Davies, Miss Eileen Mary, Utttoxeter, Staffs.
 Durden, Peter Douglas, Birmingham.
 Hammond, Peter, Birmingham.
 Hardaker, John Christopher Keith, Birmingham.
 Hume, Miss Lois Mary, Horsham, Sussex.
 Limbrick, Dennis Roger, Lancing, Sussex.
 Ryan, Kenneth, Surbiton, Surrey.
 Scott, Miss Ngareta Ann, Brighton, Sussex.

The following was admitted under Bye-Law 66:

The College of Aeronautics, Cranfield, Bucks.

BALLOTING LIST FOR NEW COUNCIL

Preparation of the balloting list for the new Council was begun by declaring vacancies.

ALBERT MEDAL

Further consideration was given to the award of the Albert Medal for 1954.

FINANCE AND GENERAL PURPOSES COMMITTEE

Sir Selwyn Selwyn-Clarke, Chairman of the Commonwealth Section Committee, was appointed to fill the vacancy on the Finance and General Purposes Committee created by the death of Mr. G. K. Menzies.

BICENTENARY COMPETITION

The following committee was appointed to plan and supervise the arrangements for the judging of entries for the Bicentenary Competition, 'Life in A.D. 2000', viz., The Chairman of Council (*ex officio*), Sir Edward Crowe, Sir Ernest Goodale, Dr. R. W. Holland, and Mr. E. Munio Runtz.

'SERIOUS ARGUMENT' BROADCAST

It was agreed to accede to the request of the British Broadcasting Corporation to record on 22nd June, before an audience of members of the Society in the Society's Lecture Hall, a programme in the 'Serious Argument' series for subsequent broadcast in the Overseas Services. (Further details will be announced later in the *Journal*.)

SOCIETY'S CHRISTMAS CARD, 1954

It was reported that Miss Anna Zinkeisen had accepted an invitation to paint, for the Bicentenary Year Christmas Card, a reconstruction of the scene at Rawthmell's Coffee House, when the first meeting of the Society was held on 22nd March, 1754.

SWINEY PRIZE

Arrangements were discussed for the presentation in Melbourne to Professor Paton of the Swiney Prize which was awarded to him in January. The prize consists of a cheque of £100 and a Silver Cup, which is now being made to the design of Professor R. Y. Goodden, R.D.I.

EXAMINATIONS

It was reported that the entries for the Easter series of examinations numbered 26,973 as against 23,788 in 1953.

OTHER BUSINESS

A quantity of financial and other business was transacted.

WEATHER MODIFICATION AND ITS VALUE TO AGRICULTURE AND WATER SUPPLY

A paper by

IRVING P. KRICK, M.S., Ph.D.,

*President of the American Institute of Aerological
Research, read on Thursday, 4th March, 1954,
with Captain L. G. Garbett, C.B.E., R.N. (Retd.),
a Member of Council of the Society, in the Chair*

THE CHAIRMAN: It is my pleasant duty to introduce to you Dr. Irving Krick, President of the American Institute of Aerological Research. It gives me particular pleasure to do so because Dr. Krick is an old friend, and one whose enterprises and activities I have followed with much interest for many years. I first met Dr. Krick when he came over in 1943 during the war with the armed forces of the United States. He came with a great reputation; indeed, his General Officer Commanding said he was a real wizard at forecasting the weather, and he brought with him a technique for long-range forecasting which he had produced himself and which he used with great success during the war in many key operations carried out by the United States Forces.

At the end of the war Dr. Krick was a Lieut.-Colonel in the Army Air Force of the United States, a Deputy Director of the United States weather services in the European theatre of war, the head of the Strategic Air Force Meteorological Service, and also a member of the United States Services Scientific Advisory Group. He was decorated for his meteorological achievements during the war. I think you will all agree that it was a very fine record.

Dr. Krick was also a pioneer in commercializing meteorology. He had the opportunity, before the war, of travelling to all the meteorological establishments in Europe, and he soon became alive to the fact that it was extremely difficult for a government-sponsored service to be able to give the time to the specific requirements of many industries in the country, and also of carrying out their scientific investigations. He thereupon started consultant services throughout the United States, and in other parts of the world. Some of you may have had occasion to use the International Meteorological Consultant Organization in this country, which Dr. Krick founded.

Dr. Krick also founded the American Institute of Aerological Research, of which he is now President, an organization which dedicates itself to the application of scientific research and engineering technique for the evaluation of weather for industry, agriculture and commerce. The part played by the commercial meteorologists in the field of weather modification shows the practicability of producing rain from clouds all over the world, and this, of course, will be of very great benefit to agriculture and water and other utility services.

The following paper, which was illustrated with lantern slides, was then read:

THE PAPER

Increases in the consumption of water for all purposes necessitate a continuous search for additional water resources. In many areas of the world the consumption

of water exceeds the amount available from normal rainfall, in spite of adequate storage and distribution facilities: the overall result is a steady and almost universal decline in water-table levels. Numerous proposals to alleviate the problem have been advanced by water conservationists. These vary in the United States from the widespread construction of small ponds in the Middle West—partially a flood control effort—to elaborate engineering proposals involving billions of dollars for the control and direction of river water run-off in the State of Texas. Suggestions have been put forward envisaging the large-scale production of fresh water for use by municipalities from adjacent salt water bodies. During this last eight years significant progress has been made in the application of cloud seeding to increase natural rainfall during storm periods. It is advanced that the application of proven weather modification techniques can provide the requisite increased precipitation for agriculture and water supply purposes more rapidly and economically than can any other proposal which has thus far been advanced.

An investigation of nature's precipitation processes indicates a very low efficiency. Nature has difficulty in precipitating up to five per cent of the moisture in air streams passing overhead during active storm situations and, during periods of no rainfall, vast amounts of water suspended in the atmosphere pass overhead without any precipitation taking place. At present there is no means of tapping this source of moisture when nature is unyielding owing to the tremendous amounts of energy involved in natural rainfall processes. Therefore it is only during periods of natural storminess that man is able to assist nature in producing rainfall from this almost endless supply of moisture. Assuming that nature may be five per cent efficient in producing rainfall, if man, by artificial stimulus, can increase that efficiency to ten per cent the amount of water that reaches the earth's surface can be doubled. For example, if rain falling at a rate 0.1 inch an hour can be induced to fall at a rate of 0.2 inch an hour, one inch of rain will accumulate in a storm of five-hour duration instead of 0.5 inch in the absence of artificial stimulation. This water is not lost to the atmosphere. It eventually returns through evaporation and transpiration, and therefore cloud seeding does not upset the hydrologic cycle, but merely increases its efficiency from the standpoint of man's requirements.

HISTORICAL BACKGROUND

A scientific approach to problems of weather modification by cloud seeding began as early as the 1890s, when patents were issued in both the United States and Europe on devices for projecting dry ice into the clouds. Certainly these inventors understood or suspected the role played by clouds containing a mixture of ice crystals and supercooled water droplets in nature's rain-producing mechanism. It was presumed by early experimenters that one could shoot projectiles loaded with liquid carbon dioxide under great pressure into likely-looking clouds, so that, when the projectiles burst, the sudden expansion and resultant cooling of this material would produce dry ice which would chill the air and result in the formation of ice crystals. These would grow at the expense

of surrounding droplets, finally becoming snowflakes large enough to fall out.

These early attempts to induce precipitation were thwarted because of a lack of current information on the state of the atmosphere. Without an accurate knowledge of temperature and moisture distribution in existing cloud systems, it was difficult to determine when, where, and how much material should be used. Furthermore, no systematic effort was made to assess results. Thus interest in these early efforts lagged and finally died out altogether.

During the first third of the twentieth century considerable progress was made in the measurement of upper atmospheric conditions, first by balloons, then with aircraft, and finally, in the years before World War II, by radio-equipped sounding devices. Also during this period theories were developed which gave more credence to the importance of ice crystals in clouds of supercooled water droplets for the development of natural precipitation.¹ An attempt at artificial rain production is described in 1931, when a Dutchman, Veraart, dispersed dry-ice pellets into supercooled clouds from an aircraft flying above the clouds.² In an effort to verify this result, Veraart obtained rainfall measurements directly under the clouds which were seeded, and compared these reports with rainfall from surrounding areas. It was his opinion that a maximum in the rainfall pattern was attained in the vicinity of his operations. On the basis of these experiments he appealed to the Dutch Government for financial support to continue and extend this operation. His efforts proved futile and again interest in artificial rain production diminished.

The subject was revived and stimulated by the experiments of the General Electric Research Laboratories in Schenectady, New York, in 1946, under the direction of Irving Langmuir, Vincent Schaefer, and Bernard Vonnegut.^{3 4} The introduction of dry ice into a cold box filled with tiny supercooled water droplets resulted in the formation of ice crystals. Recognizing the possibility of inducing precipitation from supercooled clouds in the free atmosphere in this manner, General Electric and other experimenters launched a vast effort, which, during the succeeding seven years, has yielded increasing evidence that cloud seeding to increase natural precipitation is a thoroughly sound process, technically and economically. Two approaches to the development of these early researches have been made in an effort to answer the questions 'Can man augment rainfall and by how much?' One is to make carefully controlled experiments which attempt to induce rain to fall from individual clouds. Simultaneously measurements are made of such elements as the water content, drop sizes, motions within the clouds, temperature distribution and other characteristics. In general, no effort is made to relate rainfall induced from such attempts to specified areas. Amounts of rainfall recorded during the active operating periods, in such a series of investigations, are always small compared to the total rainfall accumulated during the entire series. This approach permits the collection and verification of data relating to nature's rainfall processes and some visual evidence of cloud changes resulting from human influences. The design of the operations, however, makes it impossible to detect the quantities of rain induced artificially for reasons given later in this paper.

A second approach has been to develop cloud seeding techniques which permit accurate pin-pointing of effects during the passage of widespread and continuous rain belts. This provides for the accumulation of rainfall increases in the target area of sufficient magnitude to be detected with respect to rainfall in surrounding uninfluenced areas. Conclusive assessments of these differentials require a large quantity of data. These can be obtained most rapidly by carrying out a large number of diverse and sustained operations for long periods. Operations designed along the lines of the first approach give partial answers to the question 'Can man induce rain to fall?' but do not provide an answer to the all-important question of how much. Operations of the second type provide this answer and support the findings of the former.

Without exception all government-financed weather modification experiments throughout the world are of the former type and do not provide conclusive evidence on the economic value of cloud seeding operations. On the other hand, all commercial weather modification work of necessity has been of the second type with the ultimate object of providing a reasonable assessment of the value of water produced in relation to costs. These values can be interpreted in terms of increased crop yields, hydro-electric power production and in many other ways. Our group has been concerned with both approaches—the first to provide a basis for the second.

In 1947 the author and his associates participated in experiments conducted in an effort to discern the manner in which the early General Electric results might be applied to induce increased precipitation from large-scale atmospheric disturbances. The knowledge acquired was used in 1948 and 1949 for cloud seeding operations by aircraft, which the group supervised in Arizona, California, and Mexico.⁵ Limitations on using aircraft for broad-scale and continuous operations became apparent during this period. Considerable effort was expended during 1949 and the spring of 1950 in the development of equipment capable of continuous and properly controlled introduction of cloud seeding materials into an air stream from the ground. Investigations relating meteorological situations to cloud seeding possibilities in various parts of the world, and also dealing with economic aspects of such operations, were pursued. From these researches cloud seeding operational procedures designed to permit an assessment of results, both technically and economically, were derived.

BROAD-SCALE CLOUD SEEDING OPERATIONS

Following these developments our organization undertook its first broad-scale operation in the Horse Heaven Hills of eastern Washington in June, 1950. The objective of this project was to increase production on a wheat farm which covered an area of approximately 100,000 acres. The region is one of low annual rainfall but unusually fertile soil. Thus in the years of more than normal rainfall good crops can be grown, but dry years have proved disastrous for past generations, placing the area in a distinctly marginal category for wheat farming.

Although these early operations in the Horse Heaven Hills were strictly experimental, they were regarded by many as highly successful. Two storms

were operated, one occurring June 6-8 and the other June 11-12. The maximum in the rainfall pattern for the two storms occurred precisely over the target area. Rainfall amounts attained values of approximately 430 per cent of the June normal in the target area, diminishing rapidly in all directions. June rainfall amounts experienced over a thirty-year interval were exceeded. No conclusive assessment of the rainfall to be credited to the operation was possible from such a limited sample of data. Nevertheless news of the apparent success spread rapidly and resulted in a great increase in the number and size of broad-scale cloud seeding experiments conducted by our group in the United States and foreign countries.

Operational data, carefully logged and analysed during the past six years, have provided a sufficient sample to permit reliable estimates of cloud seeding potentialities for increasing rainfall. To date, cloud seeding from ground-based units totals approximately 200,000 generator hours from these operations. Areas of activity include eighteen States in the United States and six foreign countries. A number of projects have been operated continuously since 1950.

Principle involved

Broad-scale cloud seeding operations for increasing natural precipitation are designed to target effects accurately to designated project areas. For maximum efficiency operations are conducted during storms producing widespread and continuous precipitation.

An understanding of nature's rain mechanisms is essential to successful operations. Broadly speaking, nature precipitates water from the skies in two stages, the first stage being droplet or ice crystal formation by a process known as nucleation, and, the second, the growth and coalescence of ice crystals or drops thus produced until they fall through the air stream transporting them. Nucleation involves the formation of drops or ice crystals upon foreign matter, such as salt particles, dust, or other substances present in the atmosphere. These particles act as small nuclei which attract moisture to form water drops at temperatures warmer than freezing or ice crystals at temperatures colder than freezing. The efficiency of this process is a function of temperature and the substance upon which the moisture collects. In nature the average temperature at which freezing or ice nuclei operate is approximately -13°F .

Figure 1, reproduced from studies by General Electric, illustrates clearly the variability of temperature at which various substances act as ice nuclei.

If ice nuclei effective at temperatures close to 32°F . can be dispersed through supercooled cloud formations (water droplets at temperatures below freezing), ice crystals may be induced to form. Such substances are not observed in the atmosphere but may be induced artificially. This is the origin of the term 'artificial nucleation' in reference to cloud seeding.

At present most broad-scale cloud seeding operations for increasing natural rainfall depend upon the use of artificial ice nuclei. Rain-producing clouds in nature which attain altitudes where temperatures are colder than freezing have passed through the condensation stage before ice crystals develop. Thus

the cloud drops assume temperatures below freezing, and, as ice crystals appear, the cloud becomes a mixture of ice crystals and water droplets. Because of the difference in the saturation vapour pressure over ice and water, the ice crystals grow at the expense of the water drops.

To date, several substances not found in nature have been used effectively as ice crystal producers in supercooled cloud masses. Those used generally are dry ice and silver iodide. Dry ice operates by cooling the air with which it comes in contact to temperatures below -40°F . At these temperatures ice crystals will form spontaneously in saturated air. Silver iodide, on the other hand, can be vaporized to produce a myriad of tiny ice nuclei which will act to produce ice crystals in saturated air at temperatures as high as approximately 25°F . For

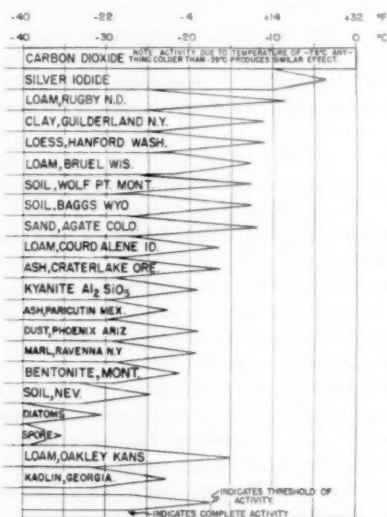


FIGURE 1. Temperature-activity relationships of freezing nuclei

large-scale operations silver iodide has an advantage over dry ice in that it can be dispersed continuously into an air stream in effective nucleating concentrations over relatively wide areas. It can be introduced into cloud masses from the earth's surface because of the natural rising motions and turbulent diffusion present in all storm situations suitable for cloud seeding. Dry-ice pellets on the other hand must be introduced inside or from the tops of clouds by aircraft or other means and are quickly dissipated in their fall through the air. Thus their effects are very limited in time and space and are usually unproductive of the important broad-scale influences required if cloud seeding operations are to be of significant benefit to the public or private economy.

Silver iodide nucleation

The principle of artificial nucleation using silver iodide is illustrated in Figure 2. Ordinates indicate altitude in feet. Characteristic temperature levels in the atmosphere over the United States on a typical summer day are indicated. A cloud formation has been introduced at appropriate levels. It may be regarded as typical of a local storm-cloud or of broad cloud sheets associated with a major storm. Temperature values shown are not characteristic of the corresponding altitudes for every weather situation. In winter or at high latitudes, for example, it may be much colder at the respective altitudes shown. The triangular form drawn inside the cloud illustrates the decrease of moisture with altitude in the atmosphere. At lower levels there is more water available for condensation and precipitation than at higher levels in the atmosphere because, at the cold temperatures characteristic of high altitudes, air will not hold as much water vapour in suspension as it will at the warmer temperatures found at lower altitudes.

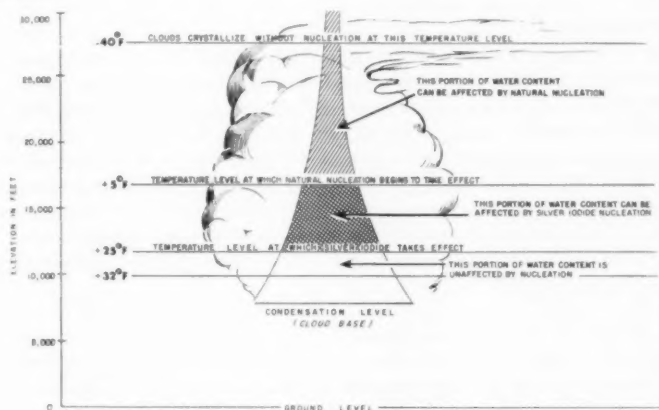


FIGURE 2. Temperature levels responsive to artificial nucleation by silver iodide or to natural nucleation (summer)

In the cloud mass depicted in Figure 2 there are three zones designated in the regions where temperatures are colder than freezing. In the lower zone, in a temperature range between 32 and 25°F., the cloud is unaffected by artificial nucleation because silver iodide crystals do not act as ice nuclei until temperatures are colder than 25°F. In the zone between 25°F. and 5°F. the water content can be affected by silver iodide nucleation. Thus this is the zone within the cloud mass in which silver iodide will form ice crystals. On the other hand, natural nucleating materials do not begin to take effect until the temperatures are colder than 5°F. and, therefore, are ineffectual within this layer of cloud. At temperatures colder than 5°F. water vapour in the cloud can be affected by substances occurring in nature which produce ice crystals. In the case of most

natural nuclei, this effect is not complete, however, until temperatures are near -13°F ., so there is still, in this segment of the cloud, an action of silver iodide in augmenting nature's ice crystal production. Finally, at levels of approximately -40°F . clouds crystallize without nucleation of any kind because this is the temperature level at which ice crystals seem to form spontaneously in saturated air.

The distribution of water vapour in the atmosphere is such that the segment of cloud affected by artificial nucleation contains much more water than the higher portions of the cloud influenced by natural nucleation. Consequently in some instances the amount of water that is precipitated to the earth by the artificial nucleation process may exceed that which is precipitated through the effects of natural nucleating materials in the atmosphere. In general, the ratio of induced precipitation to natural precipitation is greater in winter than in summer because the greater proportion of cloud mass lies at the temperature zone influenced by cloud seeding. This ratio is greater in higher latitudes than in lower latitudes for the same reason.

Silver iodide production

In cloud seeding operations it is convenient to vary the size and number of silver iodide crystals dispersed through an air stream, depending upon the particular weather situation. Several methods of vaporizing silver iodide are utilized for this purpose by various experimenters. Silver iodide in its pure form is a yellowish powder, but is not used in this state for cloud seeding. It is usually vaporized by subjecting it to a high temperature in order to produce the proper size and number of crystals for the nucleating process. The optimum temperature is approximately 2500°F . Production of silver iodide crystals as related to vaporizing temperature is shown in Figure 3. Various methods are in

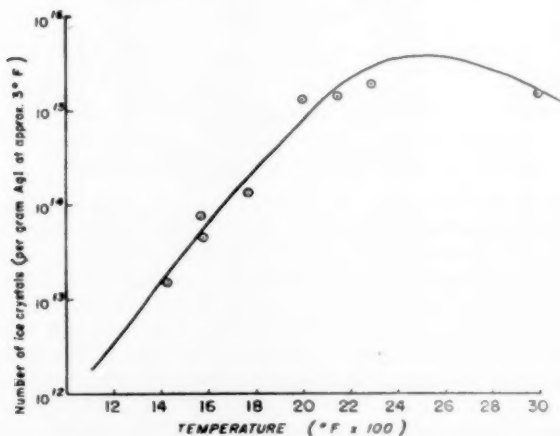


FIGURE 3. *Production of ice nuclei from silver iodide*

use, ranging from an acetone solution of silver iodide that is passed through a hydrogen or butane flame, which burns at approximately 1800°F ., to the burning of sized foundry coke impregnated with a solution of silver iodide in acetone. This fuel is burned in a furnace in which the optimum temperature of 2500°F . is easily attained. The author's group utilizes the latter procedure.

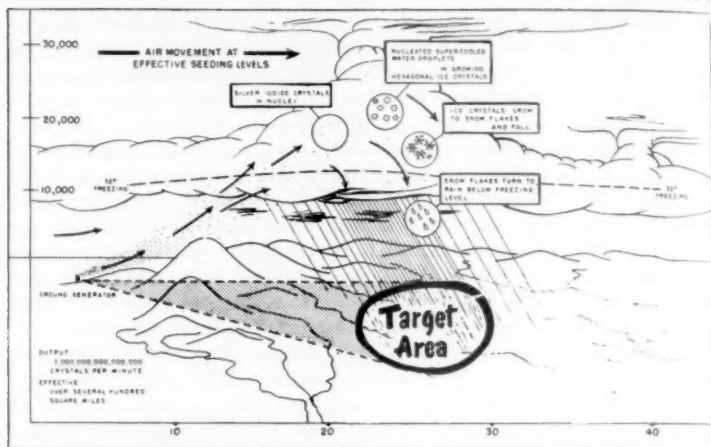
In order to insure proper crystal sizes and output from the vaporizing equipment rigorous standards are maintained in the laboratory where all lots of fuel are tested before shipment to the field. Samples of impregnated coke are burned as they come from the production line at the fuel plant. A sample of the air being emitted from the furnace is taken with a syringe device. The test is made in an ordinary cold box where a supercooled cloud has been produced, composed of droplet sizes similar to those encountered in the free atmosphere under operating conditions. The temperature of the cold box is maintained at approximately 5°F ., a range which will be unaffected by nature's ice nuclei but which will result in complete nucleation by silver iodide crystals.

The supercooled cloud in the cold box is subjected to a treatment of silver iodide crystals from the sample of air taken from the vaporizing furnace. Immediately scintillating ice crystals appear, which grow at the expense of tiny supercooled water droplets in the cloud chamber. Ultimately these ice crystals precipitate to the bottom of the box and are collected on glass slides. Viewed through a microscope a physical count of the crystals can be made and their sizes observed. By measuring the distribution of the crystals on the glass slides, a calculation of the number of silver iodide particles being produced per unit time from a given fuel lot can be made. A satisfactory output ranges between 10^{14} and 10^{16} crystals per gram of material vaporized a minute. Each particle is a potential rain-drop.

Silver iodide generator

The silver iodide fuel, composed of $\frac{1}{8}$ -inch foundry coke impregnated with controlled amounts of silver iodide dissolved in acetone, is burned in a crucible furnace which is fed from a hopper. The operation of this vaporizer must be simple and the unit must be of rugged construction for field use. Basically it is composed of a fuel hopper, feed mechanism, and vaporizing furnace. The feed mechanism and a blower for insuring the maintenance of proper temperatures in the furnace are powered by either a storage battery or ordinary electric current. By feeding the fuel into the furnace at a rate which vaporizes about one ounce of silver iodide per hour, proper crystal counts are obtained for operations under most weather conditions.

Obviously this equipment must be located so that the proper number of silver iodide crystals arrive within a supercooled cloud mass to target increased precipitation to specified areas. Figure 4 shows schematically a typical field operation utilizing ground generating silver iodide equipment. The vaporizing unit is shown on the left-hand side of the diagram at ground level. The silver iodide particles, which are invisible, are drifting downwind towards the right of the diagram and, at the same time, are rising into the cloud mass in response

FIGURE 4. *Diagram of a silver iodide ground generator in action*

to the natural turbulence and rising motions that are always present during storms favourable for cloud seeding. Lateral diffusion of the smoke plume is shown by the fan-like segment in the horizontal projection. As the silver iodide particles ascend to a level at which temperatures in the cloud mass are colder than 25°F . they begin to form tiny ice crystals. These crystals grow at rates which are determined by their initial size, the water content in the cloud, and the distance between droplets in the cloud. Assuming that the operation has been properly controlled, these ice crystals attain sufficient size to fall from the cloud as snowflakes at a point at which the maximum effects are concentrated over the target area. The precipitation accumulates as snow if the temperatures are below freezing at the ground, or as rain if the temperatures are above freezing.

Operational control

In order properly to control cloud seeding operations the diffusion pattern of silver iodide particles from ground vaporizing units as related to target area effects must be computed. This pattern is a function of the various atmospheric parameters influencing the movement of silver iodide crystals. Such calculations require not only the tracking of major storm systems in the atmosphere but the monitoring of surface and upper air observations hour by hour. Such information is available in all countries through facilities of government weather service organizations. In some instances we supplement these official weather observations by local reports from field personnel assigned to cloud seeding operations.

The diffusion pattern of particles from a silver iodide generator is determined by such meteorological factors as surface and upper air wind velocities and the rates at which rising motions in the atmosphere carry the silver iodide particles

aloft. The distance from the point of release to that where the materials become effective as nucleating particles is determined by the altitude of the freezing levels in the atmosphere. Other things being equal, the higher the freezing level the more distant the vaporizing unit must be located from the target area during operations. A cloud seeding controller must consider not only these calculations in his operations but also the potential of the particular meteorological situation to produce natural rainfall. It is during periods of continuous and widespread natural rainfall that cloud seeding operations are most productive. Primarily this potential is related to basic storm systems responsible for a major portion of observed natural rainfall. Within these systems one must consider cloud masses extending to altitudes higher than the freezing level, the vertical motions within these clouds which provide for a continuous re-supply of moisture for precipitation, and numerous other factors familiar to the well-trained meteorologist. A consideration of all of these elements makes it possible for the cloud seeding controller to determine the number and location of the vaporizing units to be operated for a particular target area. Calculations based on all storms which might have responded to cloud seeding in past years are analysed from the standpoint of current operational practices before the operation of a project to establish the strategic positions for ground vaporizing units. Generators are installed at these predetermined locations in order to operate effectively any situation characteristic of the area, once the project begins. Occasionally it is found necessary to supplement these fixed installations with mobile units in order to concentrate cloud seeding effects more precisely during a particular storm.

Through a long series of field studies the rates of ascent of silver iodide particles have been determined under varying meteorological conditions. Tracer materials exhibiting the same diffusion characteristics as silver iodide have been released and traverses performed in the diffusion plume downwind from the point of release by aircraft equipped with suitable instruments for sampling the air. Such investigations provided quantitative measurements on the distribution of seeding materials at varying distances from the generator under different atmospheric conditions. All of these studies have been integrated into the control of field operations and special skills have been developed in targeting cloud seeding effects to designated areas under all atmospheric conditions. Precipitation maxima can be achieved by these techniques in areas as small as 25,000 acres.

Because of the excellent co-operation between nations on the interchange of current weather observations it is possible, having access to these data, to control cloud seeding operations over extensive areas from a single location. For example, in North America, our operations in Canada and the United States are controlled from Denver, Colorado. Due to the complete reporting network provided by the meteorological services of the various nations in the Northern Hemisphere it is possible to monitor current operations in foreign countries from Denver as well. The use of telephone, radio, or other available means of rapid communication, insures reliable and immediate contact with field vaporizing units in all operational zones. All operational data are carefully logged at the

Natural rainfall is most abundant and widespread along the zones of interaction between air streams exhibiting different physical characteristics. In temperate latitudes these zones are located primarily between cold polar air streams and warm tropical or sub-tropical ones. In the British Isles these 'fronts', as they are called, form between cold polar air masses originating over the North Atlantic or the European continent and the warmer air streams moving northward from the vicinity of the Azores. Atmospheric disturbances contort this boundary of separation between these vast air streams to form a wave-like configuration marked by falling atmospheric pressure at its crest. These are the migratory cyclones of middle latitudes sometimes referred to as low pressure areas on weather maps. The warm air stream will pass aloft over the cold air stream on the east side of a cyclone (warm front). On the west side, cold polar air will submerge under the warm current, forcing it aloft (cold front). The rising motions in the warm air stream along these two zones of inter-action produce the major cloud and precipitation belts in a moving cyclonic storm.

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conducted in the warm air stream which, on the east side of the storm, would be moving upward over the cold air stream, and, on the west side of the storm, would be lifted by the intrusion of cold air. As the storm centre progresses north-eastward winds and temperature conditions at the surface and aloft change, thereby necessitating the use of generators other than those illustrated to maintain effective targeting to the areas shown.

The warm air stream in a storm must continually re-supply moisture to the storm's cloud systems if it is to maintain itself. This requirement accounts for the fact that a storm centre usually moves toward new sources of moisture bearing warm air. This perpetual supply of new moisture to the cloud systems of a storm permits continuous cloud seeding operations for the life of the active rain belts accompanying moving storm systems. For the same reason it is possible to target cloud seeding effects to various areas influenced by the same moving storm centre as it progresses. Figure 6 is a typical example of such operations in the United States where target areas in the States of California, Arizona, and Colorado, were influenced in turn by cloud seeding operations within the same storm as it passed eastward across the western United States. Each of the target areas was affected for a time by a belt of natural rainfall accompanying the storm. In each case natural rainfall was apparently intensified by cloud seeding operations as the rain moved across the target area. This conclusion is supported by the observed rainfall maxima in each target area. This example illustrates vividly the fact that a cloud seeding operation does not 'rob Peter to pay Paul'. In other words, the dynamic forces of nature provide

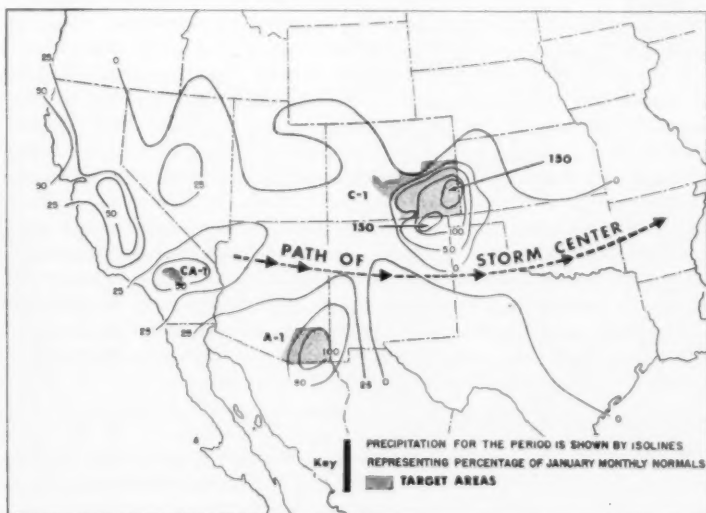


FIGURE 6. Cloud seeding for various targets affected by a moving storm area

sufficient moisture to replenish continually the cloud systems of a moving storm, thus permitting continuous cloud seeding operations in any region over which the rain belts pass.

Detection of precipitation increases

The problem of detecting precipitation increases from cloud seeding involves an analysis which will permit, within the variabilities observed in rainfall, the separation of natural from induced precipitation. In considering the design of projects in which the objective is to obtain a maximum increase in natural precipitation from cloud seeding, it is necessary to concentrate attention upon those storms permitting extended operations during periods of greatest natural precipitation. Assuming that the operator is skilled in targeting his cloud seeding effects these are the opportunities which will permit the development of a maximum in the precipitation pattern in the target area with respect to surrounding unseeded territory. If operations of this type are performed over a sufficiently long period these differentials between target and surrounding unseeded areas will be discernible through the reduction of variabilities inherent in rainfall patterns within short periods of time or individual storms.

These basic considerations have been responsible for the evolution of commercial cloud seeding from intermittent local operations from aircraft, which defy evaluation, to sustained broad-scale cloud seeding conducted from ground units which permit the accumulation of adequate data for properly assessing cloud seeding, from both the technical and economic standpoint. This difference in design and operation of cloud seeding programmes is the principal distinction between those limited operations conducted by aircraft for the purpose of studying cloud physics, and those sustained operations from ground units whose purpose is the maximum increase of natural rainfall. In most cases the seeding methods and results from the two types are not comparable. This has led to considerable confusion in the public mind because the data from isolated experiments in cloud physics are not pertinent nor capable of being correlated with cloud seeding benefits from continuous broad-scale operation. The discussion in this paper relative to cloud seeding evaluation will be confined to projects of the latter type of one year's duration or longer. In this way time and space variability are minimized in rainfall patterns, and reasonable relationships can be found between target area precipitation experience and outside, or control-area, precipitation experience when both are referred to a common denominator. This denominator usually takes the form of rainfall normals in these respective areas before the advent of cloud seeding and is called a Reference Base Datum (RBD).

Rio Alberche operation in Central Spain

On 1st October, 1952, cloud seeding operations were inaugurated to increase the flow of the Alberche River in central Spain. This undertaking was progressed for the purpose of augmenting hydro-electric power generation from plants on the Alberche River which supply a portion of the electrical energy to the City of

Madrid. The 1952-1953 water year extends from 1st October, 1952, to 30th September, 1953.

An important feature of this operation was the establishment of a formula by the engineers of the client company for assessing the results of cloud seeding. The method involved the establishment of a correlation between precipitation in areas outside the project and streamflow within the project for the years prior to 1952-1953. A reasonable relationship was found between the sum of the annual rainfall at five reporting stations in the control area outside the target and the total annual streamflow in the Rio Alberche at Burguillo for each year of record.

Figure 7 shows this relationship. For each year of record, the sum of the annual precipitation at the control stations as reported by the Servicio Meteorologico Nacional (plotted as abscissae) and the total streamflow of the Rio Alberche at Burguillo as reported by the client company (plotted as ordinates), are shown as a point. 'A curve of best fit' was derived mathematically for all of these points

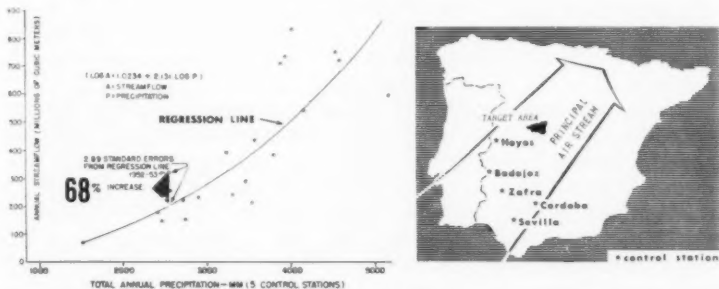


FIGURE 7. Graph of relationship between target area streamflow and control area precipitation in the Rio Alberche operation in Spain

and is drawn on the diagram as a solid line. Thus for each value of precipitation at the control stations, there will be a value of annual streamflow for the Alberche. If this relationship is changed by successful cloud seeding operations subsequent points will lie above the curve. The magnitude of the displacement will measure the increase in streamflow to be accredited to cloud seeding within the variability shown by the scatter of the original points about the curve. In Spain 1952-1953 was a very dry year because of the small number of storms which occurred. This is reflected in the precipitation reports at the control stations. In such a year all factors contributing to streamflow are minimized. Nevertheless the point for 1952-1953 in Figure 7 stands 68 per cent above the streamflow value computed from the formula. This result is regarded as statistically significant because this point is 2.89 standard errors from the line of best fit. This departure is sufficiently large in relation to the scatter of points used to establish the

correlation to reduce the chance of this event occurring without cloud seeding to less than one in 250.

Owing to the dryness of the water year, however, streamflow in the Alberche, in spite of cloud seeding increases suggested by the evaluation, was below the long-term average.

In contrast to this situation, the current water year has been favoured by more frequent storms and therefore more intensive seeding operations. The factors influencing streamflow are therefore maximized. In January, 1954, streamflow was running at approximately 130 per cent above expectancy, based upon an application of the evaluation formula for the first three months of the 1953-1954 water year. The formula for assessing the amount of water produced from cloud seeding operations is also used by the client company as a payment scheme for the programme. Since all water impounded in the reservoir at Burguillos is passed through the hydro-electric system it is possible to assess its monetary value and therefore to determine the worth of water credited to cloud seeding. Upon completion of operations for the current water year a curve of best fit may be drawn using the origin of the graph and the two points established during cloud seeding. This curve will provide a line about which future points may be expected to arrange themselves in the event cloud seeding operations are continued.

In order to confirm the physical reality of the departure of the 1952-1953 point from the curve of best fit in Figure 7 recorded precipitation inside and outside the target area were compared. All of central Spain and Portugal experienced a drought with less than 75 per cent of normal annual rainfall being recorded, with the single exception of the target area where a peak value of 121 per cent was observed. This, coupled with the added fact that in every month permitting sustained operations precipitation values in the Alberche watershed exceeded those in surrounding areas, substantiates the conclusion that at least a portion of the increment of streamflow increase in the Alberche given by the evaluation formula must be credited to cloud seeding operations.

AGRICULTURAL BENEFITS OF CLOUD SEEDING

It is more difficult to assess the economic benefits of cloud seeding to agriculture: relationships between amounts of rainfall and total agricultural production are not easily established. The timing of precipitation, the frequency of rains, as well as the total amounts of rainfall, influence the outcome of crops. Furthermore, insect infestation, blights, the incidence of hail, and many other factors, may influence the yield. However, relationships between the production of herbage on range pastures and precipitation have been established with some success. Such studies are indicative of values which may be anticipated over long periods from cloud seeding operations, not only in range pasture areas, but in adjacent agricultural regions.

The United States Department of Agriculture has carried out investigations relating the herbage production to precipitation during the preceding twelve months on a range pasture at the Desert Experimental Range in the State of

Utah. A report on this work is published in Circular 925, September, 1953.

This circular contains the following statement:

Within the limits of variation in precipitation observed at the Desert Experimental Range, herbage production increased about 46 pounds per acre (dry weight) with each additional inch of precipitation.

This study has been related to evaluations of cloud seeding operations over several million acres of this same area of Utah. Precipitation experience over southern Utah cloud seeding areas, as compared to precipitation experience in surrounding areas as adjusted for respective RBDs for the period April, 1952, through March, 1953, exhibited an increase of 3.8 inches (69 per cent). If cloud seeding be accredited with only one inch of this differential (18 per cent) according to the U.S.D.A. study cited above, the increase in net worth of forage over one million acres of western desert would be 46,000,000 pounds. This forage is valued at approximately one cent per pound and is, therefore, worth \$460,000. It has been estimated that an increase in precipitation of only .05 of an inch is required to offset the cost of cloud seeding operations for an entire year in the area. The benefits to cost ratio exhibited by this project is typical of those analysed in the United States.

SNOWPACK OPERATIONS IN THE COLORADO ROCKIES

During the past three winters, cloud seeding operations have been in progress in the Rocky Mountains of Colorado for the purpose of increasing the water content of winter snows. The water thus stored is gradually released by snow melt during the ensuing spring and summer, and is used not only for irrigation in nearby agricultural areas but also for municipal use in many cities. Figure 8 summarizes operations in various watersheds of the Colorado Rockies during the winters of 1950-1951, 1951-1952, and 1952-1953.⁷

To evaluate the effectiveness of the cloud seeding operations a control-target precipitation relationship is used. Snow water content has been expressed as a percentage of averages, computed from snow survey data before the advent of cloud seeding. Only snow course data for stations with a record of ten years or longer were used to develop this reference base datum. March data are used because they reflect the accumulation of snow during previous winter months and permit an assessment of the portion produced by cloud seeding operations through a direct comparison of target area values with those of outside areas. In this summary of three years' work it is necessary to consider the periods of operation in the respective watersheds properly to interpret the data shown. It will be noted that the Upper South Platte River watershed was operated for twelve months. This reflects a four-months' operation prior to 1st March in each of the three winters investigated. This river basin, subjected to the longest interval of sustained cloud seeding, shows the highest average water content for the three-year period, 288 per cent of the reference base datum. The next highest value, 175 per cent, appears in the Upper Arkansas basin. This river basin was operated for eight months, four in 1950-1951 and four in 1951-1952. The other river basins specified were operated for the shorter periods indicated. The equivalent of the snow water content accumulated during

this period of cloud seeding operations in the Upper South Platte has never been observed in a single year of record in any other watershed throughout the State of Colorado.

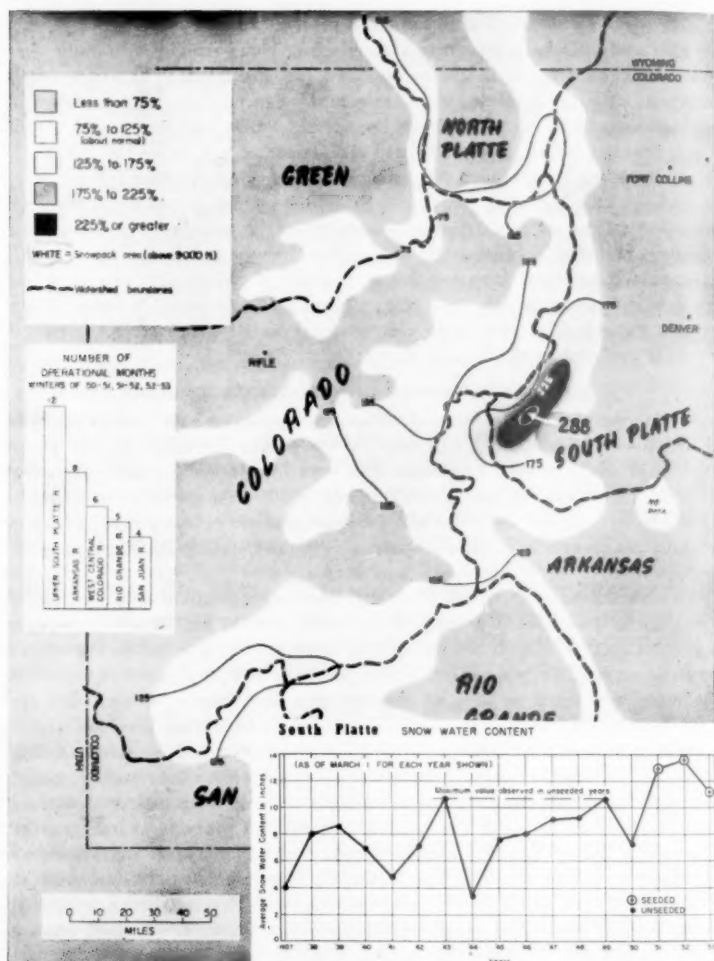


FIGURE 8. The average snow water content on 1st March in the seeded years 1950-1, 1951-2 and 1952-3, over an area of Colorado, expressed as a percentage of the average of the historical record up to 1950 (RBD). Inset is shown the historical record for South Platte, using the average for all stations used in computing the RBD.

A plot of the precipitation experience in the Upper South Platte during this period and prior to cloud seeding is shown in the inset on Figure 8. Note that during cloud seeding, the value recorded is higher for each of the three seeded years than in any previous unseeded year, in spite of natural variations in storm frequency and intensity from year to year. The statistical probability of this occurring is something less than 3 in 1,000.

SUMMARY

In conclusion, it can be stated that an examination and analysis of approximately 200,000 hours of cloud seeding operations conducted by our organization during the past six years in eighteen States and six foreign countries have consistently exhibited the following minimum increases in natural precipitation:⁸

	Increase per cent	Area
SPRING (March, April and May)	20	Southern United States, Mexico and Central America.
	40	Northern United States, Western and South Central Canada, Central Spain.
	70	Mountain snowpack operations, United States.
SUMMER (June, July and August)	20	Central America and Southern United States.
	40	Northern United States, Western and South Central Canada, Central Spain.
AUTUMN (September, October and November)	40	Northern, Western United States, British Columbia, Central Spain.
WINTER (December, January and February)	40	North-Western United States, Central Spain.
	70-80	Mountain snowpack operations, United States.

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DISCUSSION

MR. L. C. W. BONACINA: How far does the lecturer think success in this field could go without disturbing the equilibrium of atmosphere as a whole? He said something in his paper that interested me very much: he implied that, so far as

observations made in the United States went, the amount of artificial rain produced was immediately made up by evaporation. If that were true on a large scale it would give the answer to a question that has been puzzling me for a long time, and that is: if there is to be artificial rain, will the amount of natural rain over the whole globe be less, or will it be the same? If less, as would seem more likely, there would be much rain-shadowing leading to constant political disputes. But the lecturer seems to hint that it is going to be the same, and, if so, it will be a very fortunate thing because it would simply mean that that excess of precipitation, natural plus artificial, would have to be made up by a speeding up of evaporation. All the same I cannot help feeling that if this kind of thing is going to be done on a large scale there will have to be some effect on the pattern of rainfall over the globe, so that the equilibrium will be disturbed with widespread repercussions throughout the world.

THE LECTURER: I did not wish to imply that evaporation was the sole means by which moisture was restored to these storm systems. Actually it is the source of moisture existent in the warm air stream that supplies these storms as they move along. On the other hand it is true that, in the last analysis, evaporation and transpiration restore the moisture that has fallen through the atmosphere. Ultimately, if these operations go forward on a sufficiently large scale, the equilibrium of the atmosphere in the sense that we know it to-day will be disturbed. If for example you produce, by the accumulative effect, increased precipitation over a wide area, and this grows grasses and vegetation which then act as a source of moisture for transpiration in air streams passing over them, you gradually get a replenishment of the land in that area. As each new storm passes, greater evaporation occurs in the air streams that are providing moisture to the moving system. Thus an effect has been built up which ultimately will find an equilibrium level at a somewhat higher point than now. In all probability this would result in a better condition in the semi-arid or marginal areas of the world. It would simply mean that less cloud seeding operations would be required in the wetter areas of the world. That is a long range look at the problem, but it is, I feel, one which might be workable in the United States over a long period of time.

CAPTAIN S. W. BETTS, U.S.N.: Could the lecturer add a word concerning the technique of overseeding relative to prevention of precipitation?

THE LECTURER: Yes, I think that is something which aroused unfounded fears in the early days of cloud seeding. There was one school that felt that it would be possible to overseed, in other words, disperse silver iodide particles in saturation quantity so that the moisture in the cloud would be used up to form very tiny ice crystals which would never grow large enough to fall out over the immediate vicinity of the seeding area. They would have to drift along for perhaps hundreds of miles before they would encounter another band of moisture and then grow sufficiently to fall out. We have felt that that theory was again based on the concept of marginal seeding—seeding of individual clouds, clouds from which no rain was occurring. We have made extensive tests in the field in connection with hail suppression in which the objective is saturation seeding, to get as much of the super-cooled water in the cloud as possible into ice crystals in an effort to reduce the ice and quantity of hail. We have found that there is no indication that the amount of water which reaches the ground is decreased. Therefore in the type of operation we have been discussing here we do not regard it possible to overseed. In fact, following these tests, we have felt sufficiently confident in this concept to increase the concentration of the fuels that we use so that we can work further from our targets with fewer generators, and in that way get a much more uniform distribution pattern of silver iodide.

PROFESSOR G. MANLEY: I should like to ask for a little explanation on one point:

the speaker showed us a map in which he demonstrated the supposed effect of seeding parts of Arkansas and Colorado. The result showed about six and a half inches of rainfall in a small restricted area of Colorado. It also showed about two inches of rainfall in another part, somewhere in Arkansas. It seemed that there was a very considerable area in which seeding took place in which only a quarter of an inch of rain fell. There was no excess there, and in another part of the map it appeared that in an area where there was no seeding whatsoever there was a very large region in which there was two inches of rainfall. The point I should like to put is this: could the speaker show us the distribution of rain in inches, because I should like to be quite sure that in the two areas inspected which were not seeded at all there might not have been sporadic occurrences of three, four, five or six inches depending, it seems to me, very much on frequencies of gauges. One would be happier if one could see some indication of that distribution.

THE LECTURER: I think the point is important, and is the reason why individual operations—to assess the amounts of precipitation that are produced by cloud seeding—are not valid, because of the local variabilities in rainfall. Therefore we do not use a method of that type to assess the amounts of precipitation that might be induced artificially. However the method has validity in attempting to discern the control over the operation. The maximum of six and a half inches occurred in the target area and was in the region of maximum convergence in the centre of the storm, so that re-supply of moisture to the cloud systems during the interval that the storm was active was much greater than in the areas at some distance from the centre. Thus in outer belts of the storm re-supply of moisture was less effective and our operation less striking. We do not know, but there might have been local points where rainfall distribution would have shown great variability, while at the same time within the maximum of two inches. That diagram was not intended to illustrate the magnitude of increases, it was merely used to illustrate a degree of control and the fact that you are not 'robbing Peter to pay Paul', increasing the moisture in one place and denying it to another.

THE CHAIRMAN: I am sure you would now wish me from the chair to express our very great thanks to Dr. Krick for his very interesting lecture this afternoon.

The vote of thanks to the lecturer was carried with acclamation, and the meeting then ended.

The following remarks on the subject of the paper were made in a letter to the Secretary of the Society by Mr. A. Beeby-Thompson, O.B.E. Dr. Krick's comments on these are also printed below.

MR. A. BEEBY-THOMPSON: A point which was not mentioned in Dr. Krick's address and would appear to be worth a reference in the author's paper is the intensity of produced rain. It was not made clear whether seeding of clouds led to deluges or gentle showers. If in the form of cloud bursts, much damage might arise from soil erosion, or certain growing crops might suffer ill. Not having personally witnessed rainfall experiments I am quite ignorant of the subject, although I often discussed it with the late Oscar Meinzer in Washington. The cost of producing rain by seeding of clouds is also an important economic factor.

THE LECTURER: The character of rainfall from cloud systems under the influence of artificial nucleation is a subject of considerable study and investigation, both by our organization and others employing these techniques to increase rainfall. Our entire experience indicates that rainfall patterns are more uniform and drop sizes smaller under the influence of cloud seeding. This is explained by the greater numbers and more uniform distribution of freezing nuclei in a cloud system through the artificial nucleation process. Nature's mechanism for the diffusion of particulate

matter throughout cloud systems is more erratic and results in wider variations in precipitation intensity and local variability. Under artificial nucleation the number of water-collecting particles, greater than normally present in nature, result in a greater number of smaller drop sizes in the rainfall reaching the earth. All of these effects are apparently beneficial because they reduce the bombardment and consequent erosion of the soil, and they reduce surface water run-off, thus producing a higher effective rainfall for the sustenance and growth of plants.

The cost of increasing precipitation by the seeding of clouds is usually one tenth to one fiftieth of the value of the benefits derived from such operations. This assessment of cloud seeding benefits is based upon an analysis of some fifty projects for interests varying from municipal water supply to agriculture and other forms of land use throughout the United States and several foreign countries.

GENERAL NOTES

THE SOCIETY'S BICENTENARY: PUBLICITY IN THE ARGENTINE

News has been received of the activities of one of the Society's Fellows in the Argentine, Mr. A. S. Hall-Johnson, in connection with the Bicentenary. Mr. Hall-Johnson gave addresses in Buenos Aires in March on the Society's work and history to a meeting of the British Engineering Association of the River Plate and to the Argentine Association of English Culture. He also wrote an article on the Bicentenary of the Royal Society of Arts, which was published in the March issue of the monthly Journal of the British Chamber of Commerce in the Argentine Republic.

THE NAPIER SHAW MEMORIAL PRIZE

The Royal Meteorological Society announces the first competition for the Napier Shaw Prize of £100. On this occasion it will be awarded to the author of the best original essay in English on 'The energetics of the general circulation'. The competition is open to all nationalities, and essays must be presented before 4th March, 1956.

Details of the competition may be obtained from the Assistant Secretary, Royal Meteorological Society, 49 Cromwell Road, S.W.7.

OBITUARY

MR. HUBERT SCOTT-PAINE

We record with regret the death, at the age of 63, of Hubert Scott-Paine, known for his pioneering work on marine aircraft.

Mr. Scott-Paine first flew at the age of 19, in 1910, after running away from school and earning his living in a variety of ways. From then until 1914 he built several land planes, and in 1913 he designed the first circular flying-boat hull. After the First World War he opened the first international flying-boat route, and he financed the 1922 winner of the Schneider Trophy. His interests also extended to the building of high-speed motor boats.

He was a founder and a director from 1924 to 1940 of Imperial Airways, and chairman of the British Power Boat Company from his founding it in 1927 until his death. He was elected a Fellow of the Society in 1936.

NOTES ON BOOKS

A HISTORY OF FLYING. By C. H. Gibbs-Smith. Batsford, 1953. 215

Though this book is as difficult to review as the historical parson's egg was to eat, I hasten to say that the good parts are considerably greater in volume than the bad. This is the kind of history which an encouraging father should give to an aeronautically enthusiastic son. It will tell the son much of the days when his father's forebears were trying to find out the way to fly, the way of an eagle in the air, and something of the actual successes which began with the Wright brothers and are still continuing.

Mr. Gibbs-Smith is a historian in a hurry. He is also a writer, and it must be stated clearly that a writer of history cannot afford the modern mania for speed, for it will involve him in passing over, before he has time to consider their relative importance, many happenings which go to make history, and especially written history, what it is—a continuous methodical record of events. This book is not a continuous record. One has a feeling at times that the author has given more space to people or events which have interested him most than can always be justified in a book of this length and range. For example, Mr. Gibbs-Smith is an enthusiast about the Portuguese Jesuit, Father Laureço de Gusmao, born in the seventeenth century and known for his suggestion for a flying bird. The author devotes three and a half pages of speculation on the value of this suggestion. The evidence is flimsier than the seventh veil. We all have our heroes in aviation, but it is difficult to agree with the author's claim, 'Never before or since has there been such an interesting figure in the history of flying'.

Mr. Gibbs-Smith very rightly pays tribute to the work of Sir George Cayley, W. S. Henson and John Stringfellow in the first half of the nineteenth century. History, however, is a wilful jade, for she is often misleading about birth dates, until irrefutable evidence is provided about them. Mr. J. E. Hodgson, the author of *The History of Aeronautics in Great Britain*, a classic in his own lifetime, took endless trouble to check his material, but, like Mr. Gibbs-Smith, was misled both as to the date and place of Henson's birth. Both authors give the date as 1805 and Hodgson gives Leicester as Henson's place of birth. Paul Johnston, the Director of the Institute of the Aeronautical Sciences in New York, made an investigation in 1943 into the life of Henson after he had emigrated to America. Johnston was fortunate to discover Henson's diary and other documents which shed new light on his contribution to those early experiments in model power flying at Chard in Somerset nearly a hundred years previous to Johnston's inquiries. The diary discloses that Henson was born on 3rd May, 1812, at Northampton, where his father was a prominent lace manufacturer.

Mr. Gibbs-Smith has divided his history into three sections: the first, the long ages before the Montgolfiers, the second, the period between them and the middle of the nineteenth century, and the third, that, roughly, of the last hundred years. In between the sections he has written 'Interludes,' one on balloons and airships and the other on heavier than air flight. Both are excellent examples of the brief explanation of technicalities which add to the understanding of the history of technical achievement.

Mr. Gibbs-Smith writes in a lively and interesting way, but he lapses into words hardly fit for a historian to use. A pilot is said (p. 260) to have 'circuited' Britain, and helicopters are 'whirly-birds'.

But one must not take the words of Tiberius Cavallo, the first air historian, too seriously and 'inform the author of any more necessary corrections or omissions,' for it is easier to criticize than to write. The reviewer would, however, suggest that in the new edition (which the book certainly deserves to have) the 'Postscript on Yesterday and To-day' should be entirely recast. It is neither flying fish, flying fowl

nor good hovering red herring. It could be extremely good, and the author in a little less hurry would make a future reviewer say 'It is extremely good'.

Batsford's, as always, have done a first-class job of printing.

J. LAURENCE PRITCHARD

FROM THE JOURNAL OF 1854

VOLUME II. 28th April, 1854

The following advertisements appeared in this issue in connection with the 'one shilling colour box' for which the Society offered a medal in 1851, which proved to be one of its most popular awards.

SOCIETY OF ARTS.—PRIZE SHILLING BOX

of water colours. Used by H.R.H. Prince Albert, to be had of the successful competitor, JOSHUA ROGERS, 133, Bunhill row, Finsbury. None are genuine except they bear his address, and a fac-simile of the medal on the lid of the box. Sent by post on receipt of 1s. 10d. in stamps. J. R.'s unrivalled Drawing Pencils, nine shades, at 2d. each, or 1s. 9d. per dozen; and Mathematical Instruments. Manufacturer of every other requisite of the Fine Arts.

MILLER'S SHILLING COLOUR BOX.—

Approved by the Society of Arts, 11th May, 1853.

MILLER AND CO., 56, Long-acre, London, Artist's Colour and Pencil Manufacturers to Her Majesty, the Prince of Wales, the Princess Royal, and the Government Offices. To be had at the Society's House, John Street, Adelphi; at the Department of Practical Art, Marlborough House, Pall Mall; and by order through all Artists' Colourmen, Booksellers, and Stationers.

Some Activities of Other Societies and Organizations

MEETINGS

MON. 3 MAY. Geographical Society, Royal, S.W.7. 5 p.m.
T. E. Armstrong: *Northern Sea Route.*

TUES. 4 MAY. Civil Engineers, Institution of, Great George Street, S.W.1. 5.30 p.m. R. le G. Hetherington and J. C. A. Roseveare: *River Severn Scheme for the Water Supply of Coventry.*

Japan Society of London, at the Victoria & Albert Museum, S.W.7. 5.30 p.m. General Sir Ronald Adam: *The Work of the United Nations in the S.E. Asia, and Japan's Role in that Work.*

Manchester Geographical Society, 16 St. Mary's Parsonage, Manchester, 3. 6.30 p.m. T. S. Wragg: *Hardwick Hall.*

WED. 5 MAY. Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. (1) W. R. Piggott: *The Reflection and Absorption of Radio Waves in the Ionosphere.* (2) W. J. G. Beynon: *Some Notes on the Absorption of Radio Waves Reflected from the Ionosphere at Oblique Incidence.*

Modular Society, at the Royal Society of Arts, W.C.2. 7.30 p.m. J. H. Forsshaw: *Towards New Building.*

THURS. 6 MAY. Chemical Society, Burlington House, Piccadilly, W.1. 7.30 p.m. R. H. Mansie: *The Story of the Isoquinoline Alkaloids.*

Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. (1) M. Garreau: *Electric Traction Using Single-Phase 50-c/s Current.* (2) F. Nouvion: *Electric Locomotives on the Valenciennes-Thionville Line.*

FRI. 7 MAY. Mechanical Engineers, Institution of, Storey's Gate, S.W.1. 5.30 p.m. C. E. Power: *The Accountancy Service to Works Management.*

MON. 10 MAY. Geographical Society, Royal, S.W.7. 8.15 p.m. W. F. Grimes: *Exploration of Roman and Medieval London.*

TUES. 11 MAY. Civil Engineers, Institution of, Great George Street, S.W.1. 5.30 p.m. J. Dearden: *Wear of Steel Rails: a Review of the Factors Involved.* Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. K. J. R. Wilkinson: *Measurement as a Factor in Understanding.* Purchasing Officers Association, at the Royal Society of Arts, W.C.2. 6.30 p.m. H. C. Exell: *A Visit to the U.S.A.*

WED. 12 MAY. Newcomen Society, at the Science Museum, South Kensington, S.W.7. 6 p.m. *First Dickinson Biennial Memorial Lecture.*

THURS. 13 MAY. Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. E. F. Schumacher: *Fuel Supplies of the Future.*

OTHER ACTIVITIES

WED. 5 MAY. The Building Centre, 26 Store Street, W.C.1. 12.45 p.m. Film Show: *Colt Canadian Cedar Shingles.*

WED. 12 MAY. The Building Centre, 26 Store Street, W.C.1. 12.45 p.m. Film Show: *Bricks—How they are made and used.*

Sanitary Institute, Royal, at the Museum of Hygiene, 90 Buckingham Palace Road, S.W.1. Exhibition: *Dry Rot and Woodworm.*

SAT. 15 MAY. British Kinematograph Society, at Gaiety-British Theatre, Wardour Street, W.1. 2.50 p.m. *The Annual Convention.*

NOW UNTIL 14 MAY. Royal Institute Galleries, 195 Piccadilly, W.1. Exhibition of Paintings by Cyril J. Ross. (All proceeds to be distributed amongst Institutions for the Blind.)

NOW UNTIL 15 MAY. Crafts Centre of Great Britain, 16-17 Hay Hill, W.1. Exhibition: *Furniture and Pottery.*

NOW UNTIL 20 MAY. British Rumanian Friendship Association, at the Royal Hotel, Woburn Place, W.C.1. Exhibition: *Rumanian Folk Art.*

